

# **Measurement of Turbulent Fluxes and Dissipation Rates in the Coastal Bottom Boundary Layer**

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## **LONG-TERM GOALS**

The long-term goals of this project are to quantify turbulence and to understand the mechanisms and implications of turbulent mixing in the bottom boundary layer of the coastal ocean.

## **OBJECTIVES**

This project, which is a component of the Coastal Mixing and Optics (CMO) program, includes measurements and analysis aimed at quantifying turbulence and elucidating turbulence dynamics within the bottom boundary layer on the New England continental shelf. The objectives of the measurements are (1) to determine the vertical structure of Reynolds-averaged velocity and temperature; (2) to obtain direct covariance estimates of turbulent momentum and heat fluxes; and (3) to obtain indirect inertial-range estimates of dissipation rates for turbulent kinetic energy and temperature variance. The objectives of the analysis are (1) to close approximate budgets for turbulent kinetic energy and temperature variance; (2) to quantify the intensity and scale of vertical mixing; and (3) to test existing turbulence-closure models, which predict the dependence of momentum and heat fluxes on vertical gradients of Reynolds-averaged velocity and temperature. This project differs from previous observational studies of boundary layer dynamics on shelves because it aims at measurements, rather than inferences, of the most important turbulence statistics, and because it resolves not only the classically studied logarithmic wall layer, but also the outer boundary layer, where scaling and model predictions indicate that stable stratification has a major influence on turbulence dynamics, and where rigorous tests of turbulence closure models have not previously been attempted.

## **APPROACH**

The measurement approach is deployment of a bottom tripod fitted with sensors designed to measure the Reynolds-averaged and fluctuating components of velocity and temperature at several heights above bottom. The primary instrumentation is a set of seven BASS acoustic travel-time velocity sensors aligned in a vertical array between 0.3 and 7.0 m above bottom and co-located with an array of fast-response thermistors. BASS sensors have recently been modified to determine sound speed, in addition to fluid velocity, so that they provide indirect information about temperature and density. Secondary instrumentation includes a pair of temperature-conductivity sensors and a pressure sensor. A late addition was a set of three Sontek acoustic Doppler velocimeters (ADV's), all at 0.3 m above bottom and with a horizontal separation of approximately 2 m.

The instrumentation provides measurements that resolve the vertical structure of Reynolds-averaged velocity and temperature, in addition to providing direct covariance measurements of turbulent momentum and heat fluxes and indirect inertial-range estimates of dissipation rates for turbulent kinetic energy and for temperature variance. The measurements determine the dominant terms in the turbulent kinetic energy equation (production, dissipation and buoyancy flux) and the dominant terms in the equation for temperature variance (production and dissipation). The measurements will permit estimates of the scale of the energy-containing turbulent motions (via spectra of vertical velocity), estimates of eddy diffusivities, and tests of turbulence closure models (i.e., proposed relationships between turbulent fluxes and vertical gradients of Reynolds-averaged velocity and temperature).

## **WORK COMPLETED**

We completed acquisition of the instrumentation, fabrication of the bottom tripod, and testing of the measurement system at Woods Hole during spring and summer of 1996. We deployed the tripod at the central CMO site on the New England shelf in August of 1996. During turnaround cruises in October, January, April and June, we recovered the tripod, cleaned and repaired the instrumentation as needed, off-loaded data, and re-deployed the tripod. Final recovery of the tripod occurred in August of 1997.

Analysis to date has focused separately on the ADV and BASS measurements. The ADV measurements have provided covariance estimates of near-bottom Reynolds stress and inertial-range estimates of dissipation. The analysis of ADV measurements has focused primarily on effects of spatial filtering (due to the finite sample volume) and viscosity (due to the finite Kolmogorov scale) on high-wavenumber spectra and on dissipation estimates. The analysis of BASS data has focused primarily on estimates of heat and momentum fluxes, estimates of dissipation rates, and closure of budgets for turbulent kinetic energy and temperature variance.

## **RESULTS**

Our work on ADV measurements establishes that near-bottom velocity spectra are consistent with theoretical predictions based on the Kolmogorov model if we include effects of viscous dissipation and spatial filtering. This finding is significant because previous results published in the oceanographic literature, based on lower-quality measurements from older sensors, indicate a

much larger Reynolds number effect than can be accounted for by existing models of viscous effects.

Our work on BASS measurements has resulted in approximate closure of budgets for turbulent kinetic energy and temperature variance under conditions sufficiently energetic that the noise levels of the measurements are exceeded by the turbulence.

## **IMPACT/APPLICATIONS**

Our findings regarding high-frequency spectra of vertical velocity will impact future studies in which these spectra are used to infer turbulence statistics such as dissipation rate and bottom stress.

## **RELATED PROJECTS**

We have interacted with Paul Hill, who has obtained novel results regarding particle size by means of camera observations at the central CMO site. Our velocity measurements and estimates of turbulence statistics have permitted Paul to put his measurements into a dynamical context.

## **REFERENCES**

Shaw, W. J., Williams, A. J. and Trowbridge, J. H. 1996. Measurement of Reynolds stress and heat flux with an acoustic travel-time meter. Proceedings of Oceans '96, IEEE/MTS, New York.

Trowbridge, J. H., Williams, A. J. and Shaw, W. J. 1996. Measurements of Reynolds stress and heat flux with an acoustic travel-time current meter. Proceedings of an ONR workshop on microstructure sensors, Mt. Hood, Oregon.

Trowbridge, J. H. On a technique for measurement of turbulent Reynolds stress in the presence of surface waves. J. Atmos. Oceanic Technol., in press.

Voulgaris, G., Trowbridge, J. H., Williams, A. J. and Shaw, W. J. 1997. High-resolution measurements of turbulent fluxes and dissipation rates in the benthic boundary layer. Proceedings of Coastal Dynamics '97, Plymouth, U. K.

Voulgaris, G. and Trowbridge, J. H. Evaluation of the acoustic Doppler velocimeter (ADV) for turbulence measurements. J. Atmos. Oceanic Technol., in press.